Optimizing the Assignment of Parcels to Trays on a Tilt-Tray Conveyor System

Product: Parcels

KPI: Throughput

Geography: United States

Industry: Retail

Project Time: 2 months

Customer: Undisclosed

A Tilt-Tray sorter is a high-speed sortation device that sorts small and medium size parcels. Parcels get inducted into trays, and parcels can take multiple trays depending on how long they are, and when a parcel reaches its destination, the tray tilts and the parcel gets ejected. The most typical analogy for this kind of system, that generally people are familiar with is a baggage handling system in the airport (figure 1) or postal packages through systems such as UPS. In all these cases packages are diverted to a separate area of the facility and get grouped based on their destination. This avoids manual sorting down the line by human resources, which causes errors and takes more time.

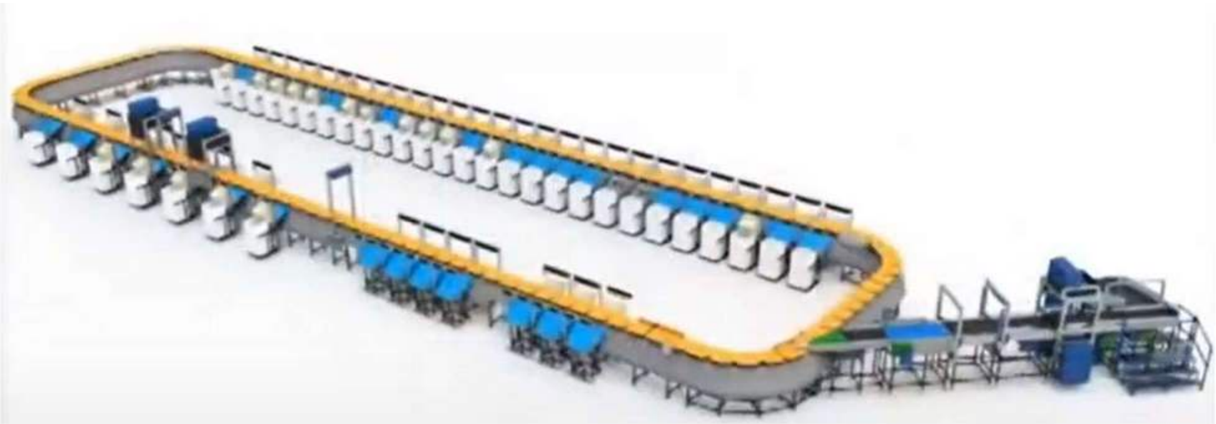

Figure 1. Tilt-Tray Conveyor

Similarly in distribution centers, as orders arrive, people are picking those orders in bulk and then tilt-tray sorters group them based on whether they go to a store or if they are an individual order or something else.

In practice, tilt-tray sorters often have multiple induction areas, with many lanes feeding the trays, and from that perspective, there’s a decision to make, which is the lane that will feed a particular tray with a parcel. Modern systems are often built with a first in first out logic, but it is also known that this way of working is sub-optimal. Additionally, there are systems with trays that have different lengths and discharges can't happen back-to-back, which means that when a parcel is ejected through an output lane, the lane needs some time to reset before it can accept a new parcel. In general, 1 to 4 trays are needed to pass before the ejection lane can receive a new parcel. This is important because every time 2 consecutive trays have parcels that are going to the same destination, those parcels will re-circulate and block new parcels from entering the system.

The Problem

There is a clear opportunity to improve the performance of these systems, and the first analysis shows that the first-in-first-out (FIFO) logic causes a 10% decrease in total throughput. This is a major number, especially for distribution centers who are completely overrun during the holidays season or parcel sorting facilities. So, if we manage to increase by 10% the throughput for each of the 10 facilities that the company normally uses, now it only needs 9.

Considering that each of these buildings costs hundreds of millions of dollars, this is a very major opportunity. Using FIFO logic is sub-optimal and there are two components to this:

- When you have trays that have different sizes, the size of the tray relative to the size of the parcel is not considered (figure 2)
- Recirculating parcels. The system needs multiple trays to pass before you can allow another parcel to enter the conveyor. This is not taken into consideration when using FIFO. So, by making smarter decisions and using other induction lanes to place parcels in the system instead and waiting an appropriate time to add the parcel, it would be possible to avoid recirculation, get parcels out of the system sooner and free up more trays.

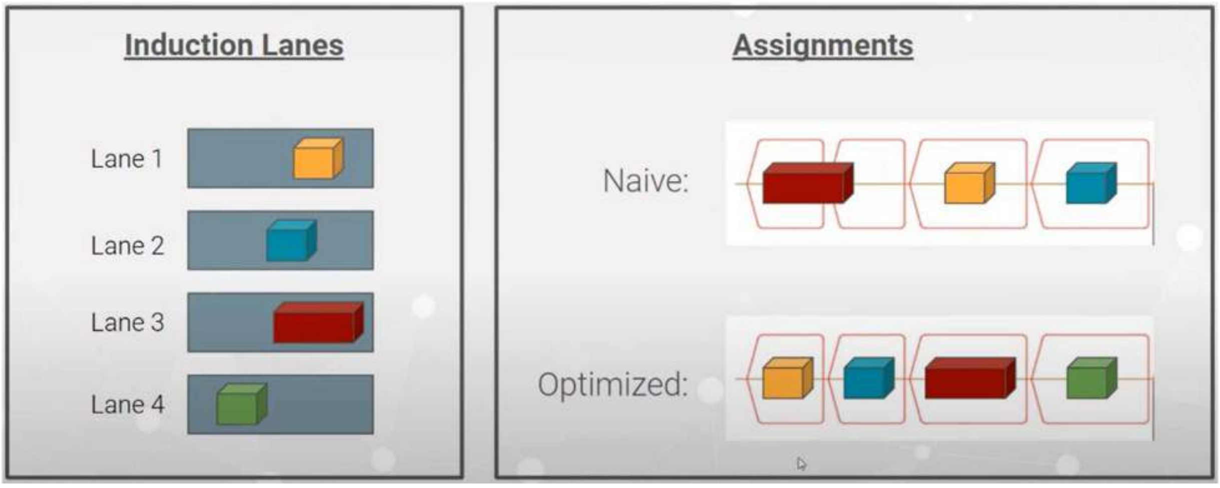

Figure 2. FIFO logic (naïve) vs optimized logic

The Solution

It is possible to solve this problem by using mathematical optimization also known as mixed integer linear programming or mathematical programming. What this technique does, is that it translates a business problem into a mathematical problem with 3 components:

- Decision variables

- Constraints
- Objective, as a linear function of the decision variables

The most important feature of using this technique is that it comes with a guarantee to give the optimal solution for the objective function. If the objective is to maximize throughput, it is guaranteed that it's impossible to find better throughput with any other method.

Generally, in the past, solving an optimization problem took a long time, but fortunately, there are currently very powerful solvers and high-power computing that can get results very fast.

The objective is then to have a perfect parcel-tray assignment that will maximize throughput.

Why Simulations?

Even though the optimization is guaranteed, there are still certain heuristics that need to be in place that are arbitrary but necessary to develop this solution. Some of these arbitrary decisions are the position of the cameras in the induction lanes, the size and patterns of trays in the conveyor system and the distribution of parcel sizes as inputs. Additionally, interacting with the production system to test the optimization algorithm is intrusive and disruptive, which is why it's better to use simulations in order to verify that the solution implemented has no concerns and will be immediately working as soon as it's implemented in the real system. A simulation also gives the decision makers and productivity managers a sense of relief and trust that everything will go according to expectations.

For this business case we had a series of different tilt-tray sorters of different sizes, with different tray patterns, and a simulation would allow to test all configurations so it would be possible to implement the solution in all sorters very quickly as soon as the tests are consolidated.

Implementation

The solution was developed using AnyLogic as the simulation Software, communicating through REST-API with python, which would call the Gurobi optimizer in order to return the tray assignment to the simulation model. This optimization was called every time a new parcel entered the system through one of the induction lanes. (Figure 3).

Figure 3. Communication Protocol

Results

The results when the system is not at full capacity are shown in figure 4. This shows the tray utilization which is the fraction of trays that are full at any given time. When the optimized algorithm is minimizing recirculation, the parcels are discharged sooner, which means they are not in the system anymore. Having the same stream of parcels arriving in the system, it is expected for a better solution to use less trays due to the recirculation problem being solved.

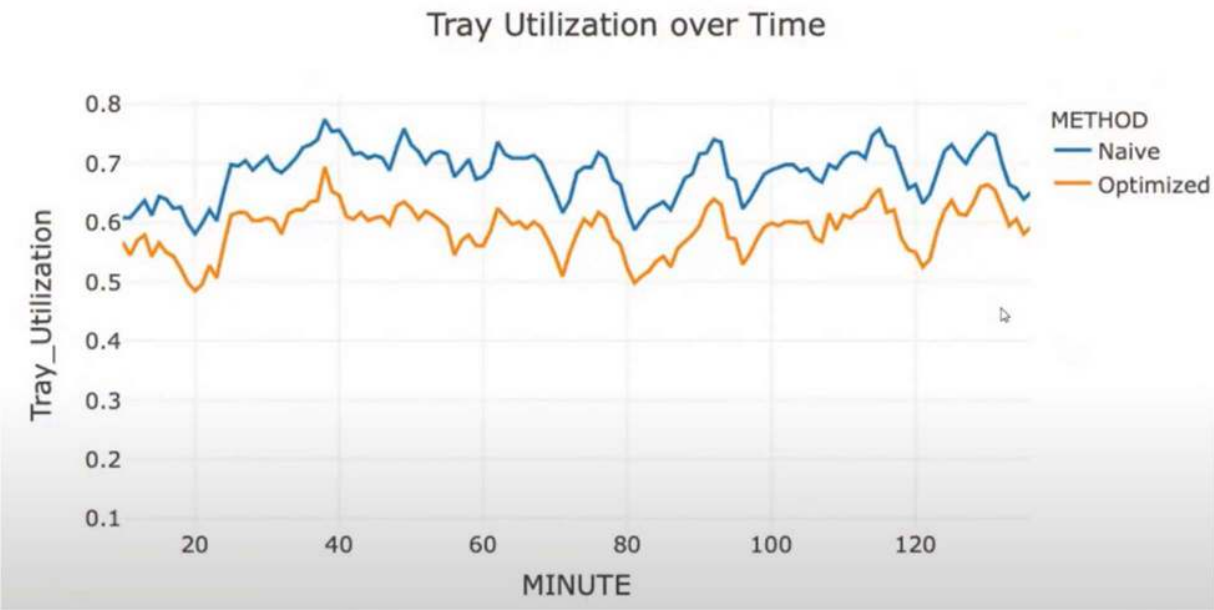

Figure 4. Tray Utilization

As the arrival of parcels is pushed up, the FIFO method will soon reach the ceiling, possibly blocking the system, with too many recirculating parcels. The optimized method allows a better tray capacity to absorb more parcels.

Conclusions

By using simulations, it was possible to prove that the implementation of this algorithm would lead to an improvement of around 10% throughput, which is associated to a value in capital of more than 100 million dollars considering that using this technique, the construction of a new facility to cover the demand is not necessary anymore. In comparison a small fraction of that amount will be used to cover the basic requirements to implement this technology, such as sensors in the induction lanes of each one of the tilt-tray sorters in use.